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OF

THE ROYAL ASTRONOMICAL SOCIETY OF CANADA

DEVOTED TO THE ADVANCEMENT OF ASTRONOMY AND ALLIED SCIENCES

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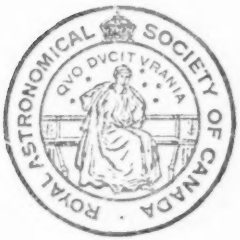

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ROYAL ASTRONOMICAL SOCIETY OF CANADA

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At Winnipeg—At Toronto—At London

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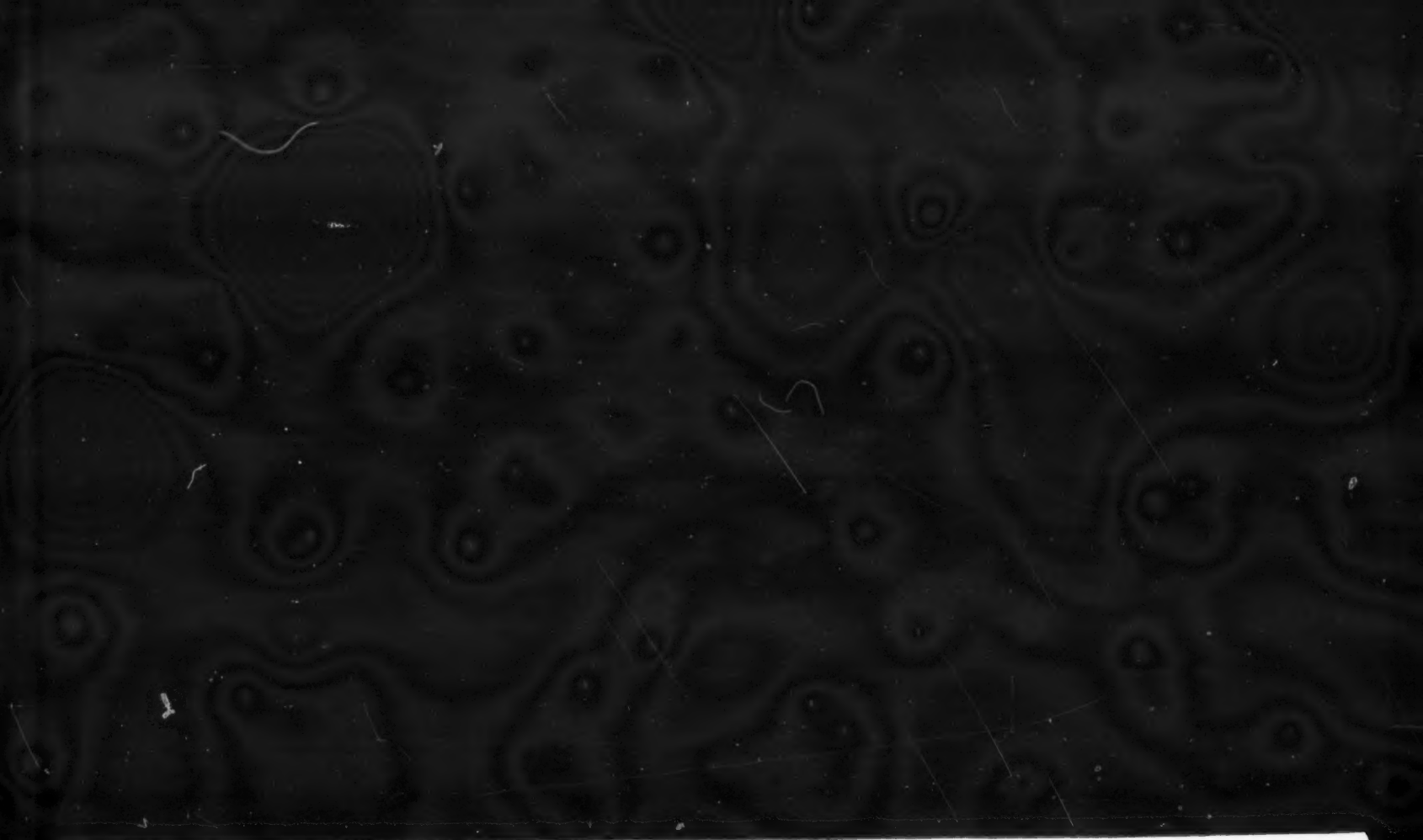
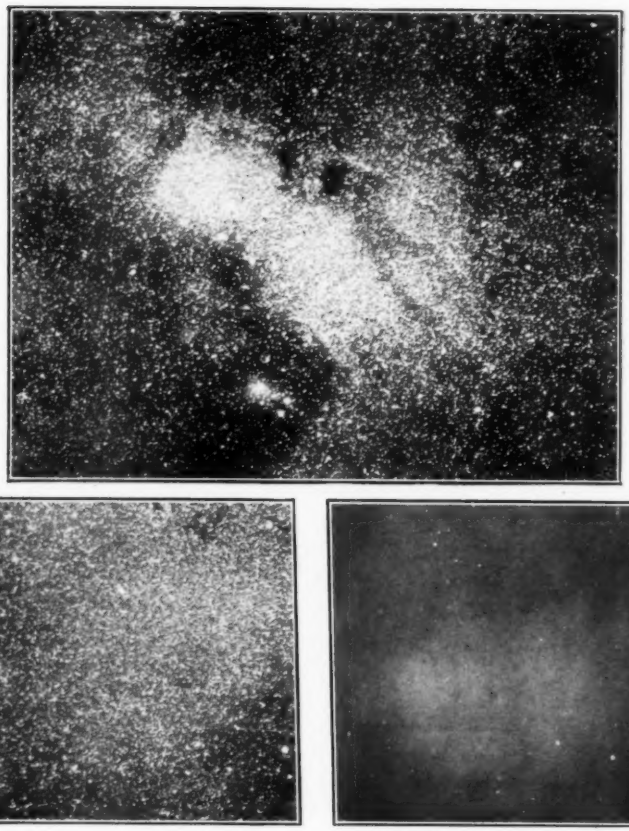


PLATE XXI

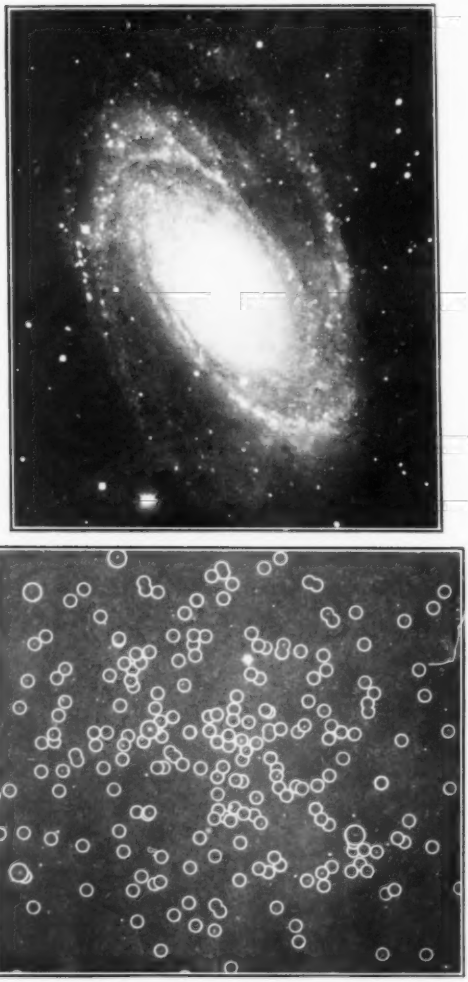


Above. A PART OF THE MILKY WAY.
(Photograph by Barnard)

Below. A DENSE PART OF THE MILKY WAY AND A BARE PART OF THE SKY.

Two photographs by H. D. Curtis with the Crossley Reflector at the Lick Observatory with equal exposure times, and each covering an area about equal to that of the full moon. That at the left is in a very dense region of the Milky Way and shows about 80,000 stars; the one at the right is some distance from the Milky Way and shows only 124 stars, illustrating the differences in stellar distribution.

PLATE XXII



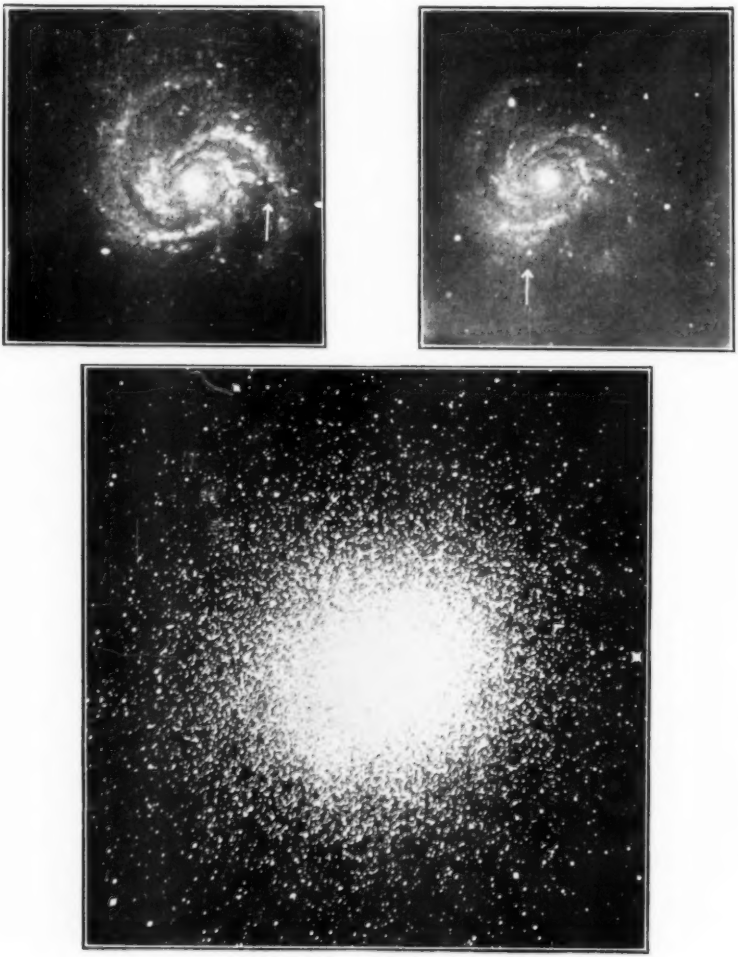
Above. A BROTHER MILKY WAY
Messier 81, in Ursa Major.

Below. AS FAR AS WE CAN GO

This indicates about the limit of our visible universe at present. Within the white rings are 247 brother Milky Ways. Light has been about 1000 million years on the road from this part of space. Photographed by H. D. Curtis at Lick Observatory.

Journal of the Royal Astronomical Society of Canada, 1928.

PLATE XXIII



Above. TWO CATASTROPHES OF FIVE MILLION YEARS AGO
Photographs of a brother Milky Way (NGC 4321) taken at Lick Observatory in 1901 (by H. K. Palmer) and in 1914 (by H. D. Curtis) showing two new stars, or novae.

Below. THE GREAT CLUSTER IN HERCULES
(Mount Wilson Photograph)

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VOL. XXII, No. 10 DECEMBER, 1928 Whole No. 179

THE UNITY OF THE UNIVERSE

By HEBER D. CURTIS
*Director, Allegheny Observatory**

In all ages and in most countries men have pondered and philosophers have speculated on the possibility of the existence of localities in our macroscopic universe where our familiar local laws of matter, energy, and even of thought, might appear under different forms from those known in our own section of space; localities where heat, light, and electricity might follow other unknown laws, where other forms of matter might exist, localities even where two plus two would not necessarily be equal to four.

The title of this address may seem to some to be an exceedingly large one, even somewhat grandiose and pedantic. Yet the motif of this treatment is one which is relatively simple. Our aim is simply to collate and to present in more or less coherent form certain modern astronomical and physical results bearing on the essential continuity—the *one-ness*—of our exterior universe. It will be seen, from such a treatment, that all modern scientific evidence denies the existence of any such favoured or peculiar regions of space; the principle of continuity seems to deny even that such regions are possible.

There is a manifest occasional advantage to be derived in detaching ourselves momentarily from the minutiæ of modern science, and in attempting to envisage some of its larger aspects

*An address given at the Philadelphia meeting of the American Association for the Advancement of Science, December, 1926.

en masse, rather than in detail. With our increasing specialization in microscopic areas of scientific research it would seem that the day must come when there will be a definite niche to be filled by what we may term a liaison scientist; an investigator who, so to speak, will specialize in generalities; whose field of work will be the unspecialization and correlation of apparently unconnected fields, and who will minutely investigate the minutiæ of investigators in a larger synthesis. While the present treatment disclaims any so large a purpose, yet it will be obliged to draw data and illustrative material from at least two sciences—astronomy and physics.

There is a concept which in the mathematical and physical sciences is frequently called the principle of continuity. This simply means that if an entity has always acted in a certain way under certain conditions it should always act in that same way in the future, given the same conditions, *and no new conditions*. Students of philosophy are more apt to refer to this principle as the idea of analogy, or probability.

As perhaps the simplest example of a continuity, let us imagine a series of numbers, beginning with 1, 2, 3, etc., and continuing forever. Though we should have to insert an infinity of decimal fractions in each integral gap to make this series truly continuous, in the mathematical sense, it forms a perfect example of a mathematical continuum without such additions. The principle of continuity evidently applies here without reservation, for the succession is always the same, nor can we imagine anything happening, or even any new condition, which would bring this continuum to an end.

Again, on every morning during at least the past thousand million years, an observer suitably situated on this earth would have seen the sun rise in the east. While the observational evidence for continuity in this phenomenon is so long and unbroken that the probability becomes almost a certainty, it is nevertheless not a perfect continuity, as was the illustration first given. For, as will be noted later, it is not only conceivable, but perhaps scientifically possible, that at some future time a cataclysm might make to cease the till-that-day-unbroken continuity of sunrise. A still less perfect example of continuity is given by the classical anecdote

of the Celt who stated that he had noticed that, if he lived through the month of April, he always lived through the entire year!

Continuity, then, or analogy, or probability, is trustworthy only when the evidence is adequate, when the continuity can be shown to exist, and when no factors are omitted. To the extent, then, that our knowledge is yet imperfect, arguments applying the principle of continuity to the material universe can be final. Still, the same conceivable lack of finality applies to all thought and all knowledge, and we may well be guided rather by the famous dictum of Joseph Butler—"probability is the very guide of life."

Any treatment of the unity of this universe[1] may well be made under four main subdivisions.

A. The space-factor. Extent and macroscopic structure of the accessible universe.

B. The stuff-factor. Identities in matter and atomic microscopic structure.

C. The time-factor. Data are here less certain.

D. The energy-factor. Conservation and identity.

In studying, in our own particular section of space, that congeries of stars which we call our galaxy, or Milky Way, our first impression is one of astonishment at its essential simplicity and its lack of variety in its larger aspects. We find no profusion of millions of species, as in the organic life on our planet. The stars themselves appear to be classified only in some ten or a dozen main genera; so far as present knowledge goes, were we given one hundred compartments in which to distribute and file the phenomena of our galaxy, it is possible that we would be unable to fill quite all the hundred pigeon-holes. Passing over for the moment the almost infinite unimportance of our solar system, the results of astronomical research of the past half-century have proved that the sun is simply the nearest star, and manifestly the most important to us.

Though we call this star the sun, it appears to be plain "run of the mill" among perhaps a billion other suns which form the

[1]Throughout this discussion the word "universe" is used in its absolute sense, referring to the cosmos *in toto*. The former practice of applying this term to our Milky Way, which is but one unit of the cosmos, is misleading and should be definitely abandoned.

local structure known as the Milky Way. It is very near the median position not only in its mass, and in its brightness, but apparently also in its evolutionary position, or age. It is a good average citizen of the Milky Way; probably neither very young nor very old; a respectable, middle-aged star. From this average celestial citizen, only ninety-three million miles distant, modern astronomical science has enabled us to postulate essential similarity for the billion other suns which constitute our Milky Way, and, as a next step, to derive some conception of the size and the structure of our particular galaxy. Any good photograph of a section of our Milky Way will show us several hundred thousand of the "brothers of the sun"; other suns so distant that light at its speed of one hundred and eighty-six thousand miles per second may have been ten thousand years on its journey from these suns to our photographic plate; ten thousand years, in each year of which the light ray has travelled nearly six times a million times a million miles.[2]

The "historical" element in such tremendous stellar distances furnishes us with an oblique illumination of very great interest; we are very definitely the "heir of all the ages" as we gaze at the external universe; it is an astounding thought that we thus observe, *and in the present tense*, manifestations of energy occurring in the remote past.

Next, what is the form of this structure called the Milky Way, in which our sun and all his planetary retinue is but a unit among his billion stellar brothers? Could we travel on the wings of light for a million years out and up from where we are now, and then look back upon our former home, our telescopes would undoubtedly show us a beautiful spiral structure; our sun and most of his billion colleagues would be merged in the haze of quasi-nebulous light near the central part of this spiral, and only a few of the very brightest or "giant" stars of our Milky Way would be separately distinguishable from so distant a point of observation. If, on the other hand, our journey were off to one side for a million years at six trillion miles per year, we should see this same Milky Way edgewise, as an elongated oval perhaps ten times as long as wide, and in no wise different from the multitude of "edgewise" spirals which our telescopes reveal.

[2]This distance, 6×10^{12} miles, known ordinarily as the light-year, is the customary "yard-stick" for expressing stellar distances.

In other words, our Milky Way of a billion suns is a relatively flat, watch-shaped, and presumably spiral structure, so large that it may take light fifty thousand years to traverse it from edge to edge, and perhaps one-sixth of that amount in thickness. There are very many such brother Milky Ways accessible to our telescopes, perhaps a million in all, and it is our present belief that all the beautiful objects ordinarily called "spiral nebulae" are Milky Ways, or galaxies, doubtless closely similar to our own galaxy in size and in number of component suns. The nearest "brother Milky Way" is doubtless the so-called Great Nebula in Andromeda, a beautiful spiral somewhat under one million light-years distant. This galaxy may be seen by the unaided eye by anyone who knows the constellations, as a faint and blurred, almost stellar, spot. The light which enters your eye as you look at this object, without telescopic aid, started on its way to you in an earlier geological epoch! (See Plate XXI).

The hundreds of thousands of such brother Milky Ways accessible to our great telescopes range in *apparent* size from the one in Andromeda, nearly two degrees in length, to minute flecks just visible on the photographic plate. There seems no good reason to doubt that all such Milky Ways are structures of roughly the same order of *actual* size. The diminution in apparent size is then, on the average, due to increased distance. The progression is unbroken; we pass from the great spiral in Andromeda, a million light-years distant, to smaller beautiful spirals whose light started on its journey to us while the dinosaur was roaming over the plains of Utah and Alberta five or ten million years ago. And still more distant, the minute flecks which are apparently our present limit of telescopic photography are so far away that light has been at least a thousand million years on the road, starting its journey not long after our earth first congealed its solid crust!

From this necessarily brief summary we see that we have before us in our present accessible universe a space continuum of tremendous extent. Is now this space-factor a true continuum in that it never ends? We have already seen that in its macroscopic structural features our universe displays a remarkable continuity; a billion suns, of the same general type, forming a Milky Way; and, vastly distant, many other Milky Ways of the same general type.

Now it is manifest that no one can give a definite pronouncement as to whether or not this space continuum may be actually infinite. The present limit of astronomical photography enables us only to say that the continuum of space and structure seems unbroken within a sphere whose diameter in miles is to be expressed by the figure one followed by twenty-two ciphers. Of course, we may, if we so prefer, avoid some difficulties and run into others by adopting the concepts of those who believe in relativity; that this universe is a quasi-sphere, of "curvature" so great that we can not detect it by any physical measurement; that within this quasi-sphere is all the matter of the universe, all the space of the universe, all the energy of the universe, even all the time of the universe, and that outside this quasi-sphere there is not even nothing!

Up till a few years ago mathematicians and astronomers taught that an infinite stellar universe was dynamically impossible, for, if it were infinite, we should expect somewhere in the realm infinite attractions resulting in infinite velocities, and the night sky would be uniformly as bright as the disk of the sun. These conclusions were, and still are, correct on the hypothesis that all space is filled with stars as densely as in the immediate neighbourhood of our sun. Lambert, and others, have speculated on the possibility of an infinite universe, but it remained for the great Swedish mathematical astronomer, Charlier, to prove, and I think conclusively, that an infinite universe is possible, provided that the stars are arranged in great groups or agglomerations, with much greater distances separating each such group from its next neighbouring group. The interesting fact is that Charlier's arrangement is essentially precisely that which we observe "outside". That is to say, we have a billion or so suns arranged in a group which we term a Milky Way, with a distance of the order of a million light-years separating such a galaxy from its nearest neighbour.[3]

[3]Charlier's proof that it is possible dynamically for the universe to be infinite dates back only some six years, and is found in a paper entitled: *How an Infinite World may be Built Up*, by C. V. L. Charlier. *Ark. for Matematik, Astronomi och Fysik*, Bd. 16, No. 22.

A brief outline of his theory is given here for the benefit of any who may desire a somewhat fuller statement than the very general one given above.

Charlier sets up "systems" as follows:

Let N_1 stars of radius R_1 form a galaxy G_1.

It is then, apparently, both mathematically and dynamically possible that the element of space continuity is unbroken, and that this outer universe may go on forever, world without end. Though only a possibility, the mere fact that such a possibility exists is most potent in its bearing on philosophical theories, particularly upon other infinite concepts, as eternity, or the idea of God.

We are on somewhat firmer ground when we pass to the principle of continuity in the materials of which our macroscopic universe is constructed. In certain aspects the simplicity of structure of the outer universe very definitely extends to the stuff from which our accessible universe is made. We already possess a remarkable simplicity and continuity in the concept that all matter is composed of charges of positive and negative electricity, that perhaps even all energy comes in certain very minute packages called quanta, and that these elements, whether charged particles or quanta, possess an astounding, precise, and absolute identity of pattern. It is also familiar to all that the chemist and physicist have found on this earth just ninety-two kinds of stuff; ninety-two arrangements of the ultimate charged particles—that is, the elements from hydrogen and helium up to lead, radium, and uranium—and many believe that no other kinds of matter are possible than these ninety-two. How far does this continuity of stuff extend? It will be shown that this universe, from limit to limit accessible in our mightiest telescopes, appears to use only these ninety-two arrangements of electrons which constitute the atoms of the elements, and perhaps

Let N_2 galaxies of radius R_2 form a super-system G_2.

Let N_3 super-systems of radius R_3 form a super-super-system G_3, etc., etc.

Then, provided only that,

$$\frac{R}{R_{i-1}} \text{ is greater than } \sqrt{N_1}$$

or, that the ratio of the radius of a system to the radius of the next lower system is greater than the square root of the number of units in the system, then the total luminosity and the total attraction of an infinite universe at any point within it will not be infinite but finite.

We see, perhaps, only a part of the system of galaxies, G_2. We do not know whether there may or may not be higher systems like G_3 and G_4, etc.

It is possible, for example, to imagine a trillion trillion galaxies (10^{24}), each composed of a billion suns like our own, and, if existing in a sphere of 10^{28} light-years radius, the mean velocity of a galaxy will be only 500 miles per second, which is about that observed.

no other single fact gives so direct a proof of the essential one-ness of the universe.

By way of preface, however, it should be admitted that there are several outstanding puzzles. Till a few months ago, one such puzzle was a kind of stuff found in the great diffuse nebulæ, of which we confessed our ignorance by giving it the name nebulium. It has very recently been shown that nebulium is due simply to highly ionized nitrogen and oxygen. Again, we give the name "coronium" to an as yet unknown stuff seen in the corona of the eclipsed sun. But we are inclined to think that all such puzzles will eventually be solved, as is already the case with helium and nebulium, and will be proved to be, not other elements (there seems now no place for them among the ninety-two) but perhaps hydrogen, helium, calcium, etc., under some special form of excitation.

But in the light of present knowledge it may be safely said that we are justified in postulating an absolute continuity in the stuff from which the universe is made. Our proof of this statement comes from the spectroscope. Every incandescent atom of a substance is a "sending station", and broadcasts only on certain definite wave-lengths, but these wave-lengths (light) are only a minute fraction of a millimeter instead of the hundreds or thousands of meters we use in radio. An atom of iron, for instance, broadcasts on over twenty thousand separate wave-lengths. But there is no need for any Radio Board to prevent "interference", as all the multitude of sending stations in all the atoms keep to their wave-length with truly marvellous precision. A spectroscope may be regarded as simply a receiving station which is capable of sorting out and segregating all the different sending wave-lengths of the atoms in that gamut of colour we call light. We find that an atom of iron or other substance broadcasts on precisely the same wave-lengths[4] here on the earth, or on our sun, or in a star so distant that light has been ten thousand years on the road. Spectra have even been taken of the integrated light of the suns in distant Milky Ways, whose atoms did their "broadcasting" millions of years ago, and in such spectra the expert can distinguish iron, hydrogen, calcium, etc., on wave-lengths identical with those formed by an electric spark a few inches from the spectrograph. (See Plate XXII).

[4]Neglecting the motion of the source and of the observer.

Our unity in this factor seems absolute. One can not well predict just how matter may act under the tremendous conditions of pressure and temperature existing in a star. Some postulate, for instance, radical changes in matter under such conditions, and as a result maintain that atoms are stripped of their outer electrons and become exceedingly condensed, so that one cubic foot of the companion to Sirius is held by such theorists to be so dense that its mass is equal approximately to that of fifteen Pennsylvania freight locomotives! But further evidence is desirable before we may accept without reserve such quasi-exceptions to the elsewhere unbroken continuity of the stuff-factor.

Our solar system is composed of a massive central star called the sun, around which rotate a number of very much smaller planets; our earth taking one year, and Neptune, the most distant, one hundred and sixty-five years to make the circuit about the central body; the system is essentially uni-planar. Modern theories have given us a remotely analogous structure for an atom—a heavily charged centre around which revolve the much more minute electrons. While we are progressing with great speed to-day in our knowledge of certain *numerical* relationships within the atom, our present atomic models, or a drawing of the atom of copper, with its twenty-nine intricately interlacing elliptical orbits, should not be taken too seriously. While present day identifications of the interrelation of spectral lines, and predictions of spectral structure can only be described as astounding, there are few who would maintain that we as yet have any real knowledge of the precise mechanism within the atom.

Is there a continuity of structure between our macroscopic and microscopic universes; is the atom a minute "solar system"? Many thinkers have been attracted by the possibility that there might be a dynamical and structural continuity between the configurations of the outer universe and those of the atoms. Such theorists have generally been astronomers unacquainted with physics, physicists without knowledge of astronomy, or philosophers unfamiliar with either.

For our answer must be definitely in the negative, and there seems to be no continuity in the actual structure and mechanism of the two contrasted universes of the infinitely great and the

infinitely small. This gap is not one of *matter*, for we have noted the wonderful unity in the basal elements; it is rather a difference in *structure* and *movement*. The difference does not necessarily lie in the tremendous difference of scale—a period of one year and a distance of ninety-three million miles for our earth, as compared with an orbit of a millionth of a millimeter, and trillions of "years" per second for the atomic "planet". No, the difference lies in the wonderful, unchanging, precise identity of pattern of the sub-atomic universe. The difference between two pins from the same paper is as the difference between the East and West when compared with the absolute sameness of two atoms of iron anywhere in the universe. While our stars and solar systems, if there be any other solar systems, are indeed structures of roughly the same order of magnitude, they possess no such absolute identity of pattern as does the atom. Here lies the essential difference.

Nor can we at all transfer our stellar gravitational dynamics to the atom, where it would seem that we must have electrical actions as well. The problem of the motion of only three bodies under gravitation is of profound mathematical difficulty, and the general solution of this problem was obtained by Sundmann only a few years ago. Even omitting electrical forces, the motions of a gravitational system of four, five, or n-bodies transcend the power of present day analysis. What must be the complexity of a molecule of some multi-constitutional hydrocarbon compound, composed of hundreds of intricate atomic systems! It would appear that it must be far more involved than the perhaps statistically random motions of a star cluster containing one hundred thousand suns. A hen's egg is quite certainly a far more complex structure than a Milky Way. By way of a prophecy as to future progress in the mathematics of an n-bodied system, it would appear that the physicist will inevitably make far more rapid progress than the astronomer. It is a question simply of accessibility and opportunity. For the passage of a star from one border of a star cluster to the other must be a matter of billions of years, while our atomic planets and clusters, fragmentary as is our present knowledge of actual conditions, go through trillions of their cycles of revolution or orbital change in one second of time.

A consideration of the element of continuity in the time and in

the energy factors of our universe lead us to conclusions which are, as yet, less certain. From the practically instantaneous viewpoint of our few past centuries of investigation, we know with certainty far less as to continuity in the time-factor than we do of the space-factor, and the material-factor. It seems reasonably certain, however, that the life of a star is a quantity to be measured by trillions of years, while it is conceivable that a structure like a Milky Way might be eternal, with some unknown alchemy changing the radiated energy of the stars back to matter again. Certain it is also that all forms of energy known here are duplicated precisely to the farthest confines of the universe as known to us. There is no spot within our ken where light, electricity, gravitation appear different from their manifestations in our laboratories. There seems certainly to be no locality where two plus two does *not* equal four. Both energy and matter display another continuity in their time-factor; apparently they are eternal, which we ordinarily term the conservation of energy. An atom of matter may possibly be changed into energy, and perhaps that energy back to matter again; it may be elevated, degraded, transformed, combined, but it appears never to be annihilated.

Let us for a moment become unorthodox scientists in that we devote some consideration to allied questions which the orthodox scientist is prone to dismiss as insoluble. We have studied the apparently absolute continuity of our universe in a number of aspects, finding that although the continuity of the basal stuff is absolute, there is a gap between the mere structure and motion of a galaxy and an atom. I am personally ready to admit another gap between the world of matter and that which we may somewhat crudely and without attempt at precise definition call the world of spirit. Of the three possible ways in which the finite mind of man attempts to envisage the infinite problem of the origin of the universe, the purely mechanistic solution appears to be the most contrary to what we term reason, as we push this hypothesis to its ultimate conclusion as an origin of the macroscopic universe. It appears to me impossible to ascribe such concepts as: $2+2=4$, Handel's "Largo", Keats' "Ode to a Grecian Urn", or the higher ethics, to mere "behaviourism", or to the chance chemical interaction or concatenation of a host of hydrocarbon molecules, under

self-created physical laws! With space, energy, matter, and doubtless time apparently continua, with no atom lost, are we ourselves the only manifestation that comes to an end, stops, ceases, dies, is annihilated, at three score years and ten? I take a tablet of aspirin for a cold. Nature, in her intricate plant laboratory, probably never has made precisely this compound, the mono-acetic-ester of salicylic acid. What we crudely call the spirit of man makes new compounds, plays with the laws of chemical action, is beginning to guide the forces within the atom, changes the face of the earth, gives life to new forms and takes life away from millions of animals and plants. A creative spirit that can not reasonably be less than the eternal continua it controls. Simply a chemical action, a flame? But it is a flame which controls its own flaming. This thing—soul, mind, or spirit—can not well be the only exception; in some way, as yet impossible accurately to define, it, too, must possess continuity. The concept is old, the arguments older, but some such conclusion appears inevitable.

In 1892 Kipling wrote a delightful, whimsical, little poem of three verses called "The Sack of the Gods", and dealing with the old, old theme of metempsychosis. After the World War he changed it to a threnody for the dead by interpolating two stanzas and adding a "whip-lash" of two lines. While the entire poem is abundantly worth the attention of the reader, I shall give here only these last two lines, which fit so perfectly the thought expressed above:

> They will come back, come back again, as long as the red earth rolls.
> He never wasted a leaf or a tree; do you think He would squander souls?

The fact was mentioned earlier that the rising of the sun in the east was not necessarily a perfect example of a continuity. Let us in conclusion revert to this theme, from the standpoint of an admitted possibility rather than probability; a scientifically imaginable break in the continuity of mankind's time-factor, even of the very atoms of his civilization and culture. I refer to the phenomena of new stars, generally called novæ.

Some of these cataclysms happened in our own Milky Way from a few hundred to a few thousand years ago, and we get the tidings now. We see them flash out occasionally, also, in the distant Milky Ways ordinarily called spiral nebulae; this, in fact,

was one of the earliest and most cogent proofs of their character as galaxies. In 1914 I photographed such a distant galaxy at Lick Observatory, and then compared it with another photograph of the same object, taken thirteen years earlier. At once it was evident that there was a star on each negative which was not seen on the other; in other words, two new stars had flashed out in this galaxy about thirteen years apart, but four or five million years ago, the news first reaching us in 1901 and 1914. (See Plate XXIII).

We are very far from knowing all the facts about the occurrence of such novæ. As a matter of fact, they are not really new stars, but are rather sudden outbursts of energy in already existing stars. These outbursts come suddenly and without warning, so far as we know, and some distant sun goes through an experience which can only be described as tremendous. Perhaps the delicate balance of the titanic forces within the star is in some way broken, but within a few days the star suddenly bursts into splendour, sending out ten thousand times as much heat and light as it had done before. Then, more slowly, it drops back in a few months or a few years to its former relative obscurity.

No theory of these sudden outbursts is entirely satisfactory. Neither do we yet certainly know just the character and the age of the stars to which this cataclysm happens, for which we must wait till some known star comparatively near to us decides to vary its age-long course by such an explosion of energy. But it is self-evident that, should such an accident happen to our sun, so that it would send out ten thousand times its present light and heat for a few months, simply nothing would be left of life on this earth; it would be a veritable—

Dies irae, dies illa,
Solvet sæclum in favilla.

Now the interesting aspect of these astronomical irregularities is this: It has been estimated that at least six such cataclysms happen per year among the stars of our own Milky Way, many of these cases being faint or unnoticed because of great distance. Assume, which is not far wrong, that there may be one billion suns in our particular Milky Way. Assume further that this sort of explosive outburst may happen to any star. Then the simple division of one billion by six indicates that this catastrophe might

happen to any star once in about 166,000,000 years, which is a relatively short interval geologically, or in the life of a star.

Manifestly the weak point in this deduction is the assumption that this cataclysm may happen to any star. The stability of our respectable, middle-aged sun may be such that no outbreak of this sort will ever be possible; or, again, this catastrophe may have happened to him back in his wild youth, trillions of years ago.

The assumption of entire continuity in the time-factor is then not an absolute one, in the rigid scientific sense, in so far as the earth and mankind are concerned. With this very improbable limitation, however, the rising of the sun in the East appears to be a perfect continuum for the next few billion years at least.

But, with it all, one constantly needs a fitting humility and an appreciation of the minor part which man may conceivably be playing in the greater scheme. Though not probable, it is scientifically possible that we and our civilization may be merely an incident. To revert again to Kipling:

> Cities, and thrones, and powers,
> They stand in Time's eye,
> Almost as long as flowers
> Which daily die.
> But, as new buds put forth
> To glad new men,
> Out of the spent and unconsidered earth
> The Cities rise again.
>
> This season's daffodil,
> She never hears
> What change, what chance, what chill
> Cut down last year's.
> But, with bold countenance
> And knowledge small,
> Esteems her seven days' continuance
> To be perpetual.
>
> So Time that is o'er kind
> To all that be,
> Ordains us e'en as blind
> And bold as she.
> That in our very death
> And burial sure,
> Shadow to shadow, well persuaded, saith,
> "See how our works endure."

THE OBSERVATION OF METEORS

By W. F. Denning

I was glad to observe the reference to meteoric astronomy and the remarks on fireballs in this Journal for September. I trust that the hope expressed, that Canadians would take up meteoric astronomy, will be realized. This branch is especially adapted for amateur research. To assiduous observers it offers ample recompense in the prospect of important discoveries.

In 1916 and 1927 two new cometary systems of meteors were discovered and more additions to our knowledge probably lie in the immediate future.

The observation of fireballs is particularly desirable. They are to be classed among the most impressive and brilliant phenomena of nature. When accurately recorded at more than one place their real paths may be determined. In England I have collected such observations since 1886, and the result has been a pretty abundant accumulation of results which have in part been published in the *Monthly Notices* of the R.A.S.

What is required is for some enthusiast in this department to ask for volunteers to take part at identical hours in a series of watches on clear and moonless nights. The issue would be a number of multiple records of certain objects, and these would supply data for computation and discussion.

All classes of meteoric appearances are interesting. The smallest shooting star sometimes furnishes an important link in the chain of facts leading up to an advance in our knowledge. It is astonishing how very attractive this field becomes when an observer possesses an acquaintance with the positions of the chief radiants. In fact the longer a man engages in the pursuit the more engrossing it seems.

It is true that in this country there has been a decline of practical interest in this subject of late years. Observers seem to have been vainly waiting for photography to do the recording for them. But eye observation is capable of very excellent results and can supply data of considerable accuracy.

Radiants may be determined by the ordinary naked eye method of registration to within one-half degree of error and occasionally less. In the case of showers of slow meteors the radiation is more diffuse and may be spread over 7 or 10 degrees. Though it is termed a point it is really a scattered region and a photographic record of paths could only define it approximately.

Bristol, September 30, 1928.

RADIO TALKS ON ASTRONOMY, OVER CFCT, VICTORIA, B.C.

By W. E. Harper

VIII. Counting the Stars

June 13, 1928.

The title given to this talk would suggest that I am likely to ask you to step outside, wherever you are, and start counting the stars above you. Well, it is possible you might be doing things even more foolish than that. I wonder how many stars there are and how many can the average person see with the naked eye? Glancing up at the sky on a clear, moonless night one might be led to exclaim that they are simply countless in number or, if poetical, would say that they were as numberless as the sands on the sea shore. But such a statement is far from the truth.

A little over a month ago I tried to describe to you one of the principal star groups, the Ursa Major group, better known as the Great Bear or Big Dipper. It is outlined in the sky by seven bright stars, three representing the handle and four the bowl of the dipper. If we were to count the stars within the bowl of the dipper we might be surprised how few in that considerable region of the heavens could actually be seen by the naked eye. Hardly half a dozen can be seen even on a very good night. The total number visible in the whole heavens to the average person would not exceed 6,000. Moreover, only one half of this number can be seen at any one time, that is, we see only those in the hemisphere above us. Thus we have the number 3,000 as seen on a beautiful clear night by the unaided eye. This is the upper limit, for by reason of the haze which hangs around the horizon and blots out all but the brightest stars it would be probably safer to suggest 2,500 as being the number of stars seen by the unaided eye on a clear night. That is considerably different to the idea that they are countless in number.

Telescopic aid, of course, increases the number enormously. A one-inch telescope will reveal 100,000; that is to say, if you used

an ordinary opera glass and had patience to go over the whole sky you would be able to detect that many. Increasing the size of your telescope increases the number seen and our own 72-inch telescope, used visually, would doubtless reveal several hundred millions.

But there is a way in which this number may be enormously increased. The human eye beomes wearied in looking through a telescope and the faint stars are not seen. But if we replace the eye by a photographic plate, keeping the telescope directed to the same section of the sky so that the feeble light from very distant stars is continuously registering itself in one particular spot on the plate, then these accumulated impressions after ten, twenty or thirty hours' exposure will eventually leave a record on the plate. This is the practical way to count the stars—namely, to photograph sample sections, count the number in a definite area and then multiply by a factor so as to sum up the whole sky.

The apparent brightness of a star has for many centuries been described by the term "magnitude". This term, as applied to a star, refers simply to its brightness and has nothing to do with its actual size. Moreover, to beginners at least, it must seem peculiar that the fainter the star the bigger is the number which represents its brightness. The earliest observers of the skies who have left us recorded observations of their brightness, divided all the visible stars into six magnitudes, the sixth being the faintest visible to the eye while the first magnitude comprised about twenty of the brightest.

The stars which were classed together under one magnitude are not exactly alike in brightness, but shade from the bright to the fainter so that exactness requires the use of fractional magnitudes. When we say that a star has a magnitude 4.5 we mean that its brightness lies half way between a 4th and a 5th magnitude star. It was found that the average 1st magnitude star was just about 100 times as bright as one of the 6th, so if we divide this range of brightness uniformly throughout the five intervening magnitudes we find a factor of 2.5 from one magnitude to the next. Thus a star of the first magnitude is 2.5 times as bright as a star of the second, which in turn is 2.5 times as bright as that of a 3rd, and so on. This scale has been carried backwards to the faintest stars that

can be recorded on the photographic plate with prolonged exposures. To-day we speak as freely of stars of the 15th and 16th magnitudes as the first astronomers, Hipparchus and Ptolemy did of the 5th and 6th magnitudes, although the latter have 10,000 times the brightness of the former.

How many stars are there, then, in each magnitude division and how does the scale increase? While we have stated that there are 20 first magnitude stars yet if we rigorously excluded a few which hardly measure up to standard 15 would be a better figure. In these talks, however, while accuracy is always striven for, yet it is much easier to give results in round numbers, and they will be sufficiently close to the truth to serve our purpose. The number brighter than each magnitude is approximately as follows. Each magnitude, of course, includes all that precede it.

Mag.	Number
1	20
2	50
3	150
4	530
5	1,620
6	4,850
10	324,000
15	32,000,000
20	1,000,000,000

Thus for those brighter than, or equal to, the sixth magnitude, which was stated to be the limit of the unaided eye we have 4,880 or roughly 5,000 as I stated at the beginning. The number brighter than the 10th magnitude is 324,000 and, as a matter of fact, the positions of approximately this number of stars were determined by Argelander using a telescope only 2½ inches in diameter. We see how rapidly the numbers mount up until the number of one thousand millions is reached when we go down to those as faint as the 20th magnitude.

Speaking in a general way the more distant a star is the fainter it will be. The 10th magnitude stars are on the average much more distant than those of the 5th, although there may chance to be an individual star of the fainter class which is closer than its brighter

associates. The question sometimes arises: Is there a limit beyond which the stars do not extend or do they simply go on and on to infinity, requiring only sufficiently powerful telescopes to reveal their existence.

If they extended to an infinite distance then they would be infinite in number, and while each individual faint star would not be perceptible their combined effect would cause a general illumination of the night sky such as we know does not exist. No, the universe of stars as we usually think of it does not extend without limit.

It does, however, extend farther in one direction than in a direction at right angles. We can see this for ourselves by a casual examination of the sky. We can see a band of light stretching around the heavens from southwest to northeast at this time of the year. This is the so-called Milky Way, and it is simply due to the fact that the stars extend to greater distances in that direction than in a direction at right angles. The milkiness is simply the suffused light which comes from myriads of faint distant stars. The two-thousand million stars comprising our universe are thus congregated in space in the form of a discoid, much as if we placed two dinner plates face to face. Our solar system happens to be near the central plane, and when looking out towards the Milky Way we are simply looking out along the long diameter of the universe where the stars extend to their greatest distances.

In counting the stars, then, it is necessary to have the photographs we are to use representative of the heavens as a whole and so sparse regions and thickly populated regions are taken in the ratio in which we find them actually existing in the heavens.

IX. Dead Worlds

July 4, 1928.

In my talk on "Counting the Stars" I gave you the number that can be seen by the unaided eye and the greatly increased number that can be seen with the aid of telescopes. While 5,000 is the limit for the unaided eye yet long exposure photographs with modern telescopes make us aware of the existence of 2,000 millions of stars. All these are glowing bodies of immense size similar to our own sun.

To-night I wish to say something about the stars which have ceased to shine or which shine so feebly that they send us no direct message of their existence. In recent years we have come to recognize the fact that there are these dark stars, possibly one in every three being of such a nature. And this is not because they are so far away that their light fails to carry across the depths of space; it is rather that they are not at a sufficiently high temperature to send out a glow—in them the spark of life has almost died out.

A good illustration of this is the case of the moon, although it must be remembered that this body is exceedingly small compared to the stars we are considering. Of itself the moon gives out no light at all; what we see as moonlight is simply sunlight reflected from its rocky surface. On the rare occasions when the moon comes directly between us and the sun we have an eclipse of the sun, and at such times the moon appears simply as a dark opaque object screening off the sun's rays and giving out no light whatsoever of its own. Of course, we happen to know from other considerations that the moon emits no light of its own but it is satisfactory to have such a visible demonstration of its deficiency in this regard.

In a somewhat similar way we have learned of the existence of bodies of stellar dimensions which give out no light at all or one so feeble as to amount to the same thing. Certain bright stars were noticed to rapidly lose their brightness at regular intervals and later recover it with equal rapidity. In these cases it was surmised that possibly there were two bodies, physically connected and revolving the one about the other, one being luminous and the other giving out no light. When the dark body was between us and the bright one an eclipse would occur just as in the case of the sun and moon. The earliest known and best example of this class of eclipsing binary is a star named Algol, which regularly every 2 days, 20 hours and 49 minutes circles around a dark companion whose mass is about one half of its own. During five hours of this time it loses two-thirds of its light; during the next five hours it recovers the loss, and for the remainder of the period remains constant in light. Now if the second body were completely dark and its size greater than that of the luminous star and if, in addition, it came directly in front of the bright star, then

we would have a total eclipse and no star would be seen at all. The chances of the light being completely cut off are exceedingly small, however, and partial eclipses are the rule.

By measuring the amount of dimming that occurs, and the percentage of time required to effect the same, it has been possible to deduce a great many physical characteristics of the stars that otherwise would never have come to light. Under certain conditions we can tell the masses of the bodies and these masses are of the order of our sun's mass, though possibly a little greater. Knowing the size the bodies must have to intercept the light they do we can thus deduce their densities, finding some several times as dense as our sun, but on the other hand finding some with densities 1/100 or even 1/10,000 as great as that of the sun. With refinements being made in instruments for measuring the quantity of light a star sends us, it is not surprising that many are being added yearly to the known list of such dark suns.

And in this connection there is an item of interest for some people, whose number is fortunately decreasing as the days go by, who can see no use in time and energy being devoted to such non-practical things as studying the variations in a star's light. These variations are exceedingly small in some cases, and to detect them it is necessary to use in the instruments materials highly sensitive to light. The experiments carried out in this connection with various metals resulted first in the choice of the metal selenium, for light falling upon its surface alters its electrical resistance greatly and such can be easily measured. More recent photo-electric methods have been perfected for this work which register the very slightest variations of light and now the astronomer's tool, which had been perfected for such investigations, has been adopted by radio concerns for sending out wireless photographs. The lights and shadows that play over an actor's face as he speaks his part are registered by this sensitive instrument electrically, and the electric impulses go over the ether and, being converted into light, variations appear on the screen as a composite photograph simultaneous with the spoken word. Who will dare say, then, in the face of such practical applications of the astronomer's work that it is wasted or misapplied energy.

But, to return to our subject, there are other ways by which

these dead worlds may reveal their existence than by occulting their bright companions. If a star consists of two components they will be in mutual revolution about each other, and each will be alternately approaching and receding from the earth. This motion can be registered with the spectroscope. If only one star is bright, then only one set of markings appear in the analyzed light. In this way we have learned of the existence of many stellar bodies too faint to give us light, yet almost as massive as the light-giving component. Nearly 4,000 such are known to date, and it is possible that one star in every three has such a dark companion.

Our Victoria observatory has done a great deal of work along this line, probably more so than any other observatory in the world. The periods found for such binary stars run all the way from a few hours, where the components are close together, to several years where they are far apart.

You will perhaps wonder why some are dark whilst their companions are luminous. It is a long story, but, briefly, it may be stated that stars have an evolutionary history; they are born, grow to maturity and die, though the intervals of time required for such processes are reckoned in hundreds of millions of years. Starting as a nebulous mass the stars begins to glow with a reddish hue at a temperature about 2,000° C. and with increased contraction the temperature rises to 20,000° or 30,000° when it is of a bluish-white colour. Thereafter it proceeds on the downward pathway to extinction and oblivion. Now the more massive stars proceed at a slower rate than the less massive ones, and thus we find them in all stages of brightness.

Will all the luminous stars eventually become dark? We know that, like our sun, they are radiating away energy unceasingly at the expense of their mass. What becomes of this energy? Is there a reverse process wherein these radiations are again transformed into mass and go to build up other forms of matter? Such questions would require another evening to answer properly.

X. Shooting Stars

August 8, 1928.

On a previous occasion I spoke to you concerning the total number of stars that could be seen. I gave the approximate number

of 2,000 millions as being the grand total of those of whose existence we were aware from long exposure photographs. I have also told you something of the dead worlds in existence, those stars which are at too low a temperature to shine. For every three or four of the luminous ones we have one of the dead variety.

To-night I want to speak of what are popularly known as "shooting stars". On a clear, moonless night, a bright object suddenly flashes out in the sky, darts across the heavens, leaving a trail of light, and disappears almost as suddenly as it came. One is led to exclaim: "Oh, look! see the falling star". But on seeking to learn which one of the stars has left its accustomed place and plunged into space we find that all of them still shine as they did before; none has disappeared. My audience, I feel, realize that were any of the real stars which are millions of times the size of our earth to plunge through the abyss of space such would be a catastrophe on a gigantic scale indeed.

No, these star-like objects which shoot across the clear sky have no such origin, they are caused by very tiny particles of matter which, moving through space, come into contact with our atmosphere and are set aglow by reason of the resulting friction with the air.

Ideas formerly held that space between one star and another was empty have had to be given over, because instruments now detect the presence of nebulous clouds permeating throughout space, the material of which is of infinitely small dimensions and yet whose mass in the aggregate is of a high order. Similarly in the space about the sun and its planets there are particles of dust and larger fragments of matter, all pursuing their regular paths about the sun, yet too small to be seen even with our largest telescopes. When, however, any of these particles happen to pass near enough to the earth they are diverted from their usual paths. They enter our atmosphere at an altitude of about 70 miles with a speed from 10 to 40 miles per second. If the particles are small the friction is so great that they are literally burned up. If the bodies are larger—say a few feet in diameter—their surfaces are fused over during the passage through our atmosphere. If they should come sufficiently close to the earth to be attracted to it they will fall to earth, otherwise they pass on into space as ships that pass in the night.

Calculations show that even the brightest of these meteors, as these "shooting stars" are called, have masses less than an ounce. No wonder they burn up and fall as finely divided ashes to the earth. It is estimated that every 24 hours several millions enter the earth's atmosphere, so what a wonderful screen our atmosphere is, protecting us from the bombardment of these particles from outside.

As the average duration of a meteor's flight is about half a second, knowledge concerning them is hard to obtain. Practice, however, makes it possible to plot their paths, and it is found that when traced back they often radiate from the same point in the sky. This simply means that the meteors are travelling in parallel paths, for tracing parallel lines like railway tracks back to a great distance always shows them as appearing to converge to a point in the extreme distance. Thus there are groups or swarms of meteors travelling along the same highway. This is the particular reason why I chose this subject for this occasion as next Saturday and Sunday, the 11th and 12th of August, we cross the right of way of one of these meteoric swarms and will receive a much heavier bombardment than usual.

I am sure many at least of my younger hearers will be sufficiently interested to watch for them next Saturday or Sunday night. In the early part of the night the point from which they appear to emerge lies low in the north-east. Towards daybreak this radiant point will be nearer the zenith. The latter half of the night produces more meteors than the first half because then we are going head on into space, whereas in the first part of the night we are on the following side of the earth.

A great deal of our knowledge of the earth's upper atmosphere has been obtained through the observation of the speed and brightness of these shooting stars. Amateurs, not professionals, deserve the bulk of the credit. In these days of radio reception such knowledge of the density and composition of the earth's upper atmosphere is very desirable.

The reason for the meteors appearing to travel together should be given. It is simply that at some time in the past the particles now travelling separately in paths about the sun were united in a more compact group like a comet. Disruptive forces have forced

them asunder, but true to their early training, they follow approximately identical paths about the sun as a centre.

If anyone is sufficiently interested he can make worth-while observations by using a straight edge 4 or 5 feet in length. By rapidly aligning this wand with the direction of the meteor's flight and tracing the path back we get the point where the eye first glimpsed it. Plotting with respect to the neighbouring bright stars would suffice to determine the position.

I shall have something to say at another time about the heavier masses which sometimes fall to earth and are seen in our museum as meteorites.

XI. Meteorites

September 12, 1928.

In my last talk I dwelt upon the display of "shooting stars" or meteors visible on the nights of the 11th and 12th of August. We learned that these meteors are extremely small particles of matter which, moving through space with high velocities, come into contact with our atmosphere and are literally burned up by reason of the friction resulting therefrom.

The early hours of the 11th were clear and some quite bright ones were seen. I counted six in half an hour, and very likely the display after midnight, when the greatest number can be seen, would have been very well worth watching. Unfortunately for us in Victoria, the sky clouded and remained so on the following night also. However, the rain which stopped the rather serious forest fires was more valuable, I suppose, than any observations of the meteors we might have made. Nevertheless, I hope some of you within the range of my voice were forutnate enough to see a goodly number.

While the particles that plunge into our atmosphere are usually so small that they burn up immediately, there are occasionally larger masses which plunge to earth before they are consumed. These are known as *meteorites*, and it is about them I shall speak this evening. Their number is, of course, very small compared to the others, but on the average probably four or five every year are found after they have been observed to fall.

Some six weeks ago press despatches stated that a large meteor had been seen over Portland and Seattle and had dropped in Puget Sound. Recent visitors to the Observatory here have incidentally remarked that their attention was attracted to it by a swishing noise, and on turning around they saw a great trail of light. Had the flight ended on land the meteoric body would likely have been recovered.

The mass that falls may be in a single piece or it may burst into fragments when near the earth. The largest single mass, believed to be a meteorite though not actually seen to fall as such, is the one brought back from Greenland by the Arctic explorer Peary. It measures approximately $11 \times 7 \times 5$ feet and weighs $36\frac{1}{2}$ tons. It is in the American Museum in New York.

Such a meteorite falling to earth ages ago is believed to be the image set up by the Ephesians and worshipped as the great goddess Diana.

Our museums contain many smaller specimens that have been recovered in various parts of the earth. Unfortunately there does not happen to be any specimen in our Provincial Museum at Victoria. Such a deficiency in a museum so complete in other respects should be remedied at the first possible moment. If we know of a meteor plunging to earth, steps should be taken to recover it and have it placed in the museum.

In regard to the appearance of the meteorite we find that in its swift motion through the air its surface becomes fused over with a thin black crust, sometimes glossy like varnish. This crusted surface is often pitted with small depressions where the fusible substances have burnt away more quickly than the rest. Many people are under the impression that these bodies are very hot when recovered. We must remember, though, that they come from interplanetary space where the temperature is very low, and in their momentary passage through our atmosphere only the outer surface has time to be heated up. The effect is only skin deep, so to speak, and unless the meteorite is recovered immediately the heat will have radiated away.

A large number of the meteorites are stones, pure and simple. Others are mixed with iron and, to a lesser degree, with other substances. All told, about 30 elements have been found in them but

none which are unknown upon the earth. It is hard to estimate actually the proportion of iron to stone meteorites as the former are recognizable as such even though they were never seen to fall; a feature which is not true of the stony variety. A recent discussion of over 400 meteorites which have been classified shows the proportion by weight of iron to stone as 2.5 to 1. In our earth the proportion of iron is much greater, probably 4 or 5 to 1 and thus the evidence seems to indicate that the bodies of which these meteorites are fragments are unlike the earth or possibly any of the other planets.

In speaking some time ago on the moon I mentioned that one theory advanced to account for its pitted surface was that meteorites had splashed into it while it was still in a somewhat plastic condition. We have a counterpart of such craters in the great meteor crater near Flagstaff, Arizona. Aeroplane photographs of it show a remarkable similarity to the lunar craters.

The diameter of this giant crater in the Arizona desert is 4,000 ft. The walls rise 150 feet above the surrounding country whilst the bottom lies 600 ft. below the general level. It has every appearance of being formed by an enormous meteorite or group of meteorites plunging to earth. Thousands of little fragments of iron meteorites have been picked up in the vicinity, and artificial borings show that the matter at the bottom of the pit has been pulverized to a great depth.

As trees 700 years old are growing on the rim the event must have occurred at least some time earlier. It is thought that valuable minerals lie imbedded in the head of the meteor and different companies have been organized to recover them. Untold difficulties have been encountered by the early workers in these drilling operations, but they seem to be nearly overcome now. Platinum is one of the products that they expect to recover from the head of the meteorite.

Probably the most devastating meteorite or group of meteorites came to earth in the wilds of Siberia on June 30th, 1908. The place is rather inaccessible, and it was only in February, 1927, that an expedition was organized by the Russian Academy of Sciences to locate the meteorite. The place of the fall, in the province of Yenissei, is a natural depression surrounded by hills.

Before the fall it was covered by dense primeval forest. Now it is bare, with trees uprooted and scorched in a manner quite different from that resulting from an ordinary forest fire. This scorched area is some twenty or more miles in diameter, and in the central region the ground is furrowed as if by some gigantic tool.

While reports are somewhat conflicting, as the nearest settlements were a considerable distance away, there is unanimous testimony as to the terror inspired by the fall. Even forty and fifty miles away the heat wave accompanying the group was felt while the air-wave wrecked dwellings at the same distance. Railroad officials 400 miles from the scene of the fall, though probably in the line of the meteor's flight, felt the air-wave and heard a roaring sound. The engineer stopped the train thinking it was an earthquake. It is stated also that there were 1,500 domestic reindeer in the forest and all were literally annihilated. It is rarely that one hears of such destruction of life. The phenomenon was of exceptional intensity and in a settled community would have taken fearful toll of life.

In this connection I was interested in reading a day or so ago in a recent scientific journal of an instance where a meteor occasioned bodily injury. The incident happened near Tokyo, Japan, and is vouched for by an astronomer whom I know personally, so that it may be considered authentic. This meteor hit a little child in the neck in two places, one being a mere scratch while the other was a somewhat severe burn. Her sudden cry brought her mother, who at first could not understand the cause but soon found in the folds of her dress a small hot stone. This missile, not over a quarter of an inch each way, was examined by scientists and pronounced to be a tiny meteorite, just arrived from outer space.

Here we have a rare example of a meteorite striking a person. I believe there are only two other cases known, but probably the reference in Joshua X, 11, has to do with a similar happening.

THE ASTROPHYSICAL OBSERVATORY OF THE CALIFORNIA INSTITUTE OF TECHNOLOGY*

The International Education Board, at its annual meeting in May, authorized its executive committee to provide for the construction of an astrophysical observatory, equipped with a 200-inch reflecting telescope and many auxiliary instruments, for the California Institute of Technology in Pasadena. A prime purpose of the gift was to secure for the new observatory the advantage, in its design, construction and operation, of the combined knowledge and experience of the strong group of investigators in the research laboratories of the institute and in the neighbouring Mount Wilson Observatory of the Carnegie Institution of Washington. The assurance of such co-operation and of the willingness of the institute to assume full responsibility for the establishment of the observatory and its maintenance when completed were accordingly made conditions of the gift. These conditions were unanimously agreed to by the board of trustees of the institute, and the executive committee of the International Education Board has ratified the arrangement and provided for its execution.

The prompt action of the institute trustees was made possible by the fact that on May 13 President John C. Merriam, of the Carnegie Institution of Washington, with the unanimous approval of the executive committee of the institution and of Director Walter S. Adams and his associates of the Mount Wilson Observatory, cordially accepted a request for co-operation from the California Institute and assured the International Education Board of the willingness of the Carnegie Institution to join in the proposed undertaking. Formal approval has thus been given to the continuation and extension of the co-operation which has been in progress between the California Institute and the Mount Wilson Observatory for several years, especially in the study of the astronomical, physical and chemical aspects of the constitution of matter.

The purpose of the astrophysical observatory is thus to supplement and not to duplicate the Mount Wilson Observatory. The

*From *Science*, November 9, 1928.

chief problems in view are those which naturally fit into the general scheme of research in which the two institutions are engaged. Thus the increased light-collecting power of the 200-inch telescope should permit further studies of the size and structure of the galactic system, the distance, radiation and evolution of stars, the spectra of the brighter stars under very high dispersion, the distance and nature of spiral nebulae and many phenomena bearing directly on the constitution of matter. The possibility that a 40-foot Michelson stellar interferometer, designed to rotate in position angle, may be attached to the telescope is under consideration. The measurement of the separation of the components of any spectroscopic binary stars within the range of such an instrument would give very complete information regarding the nature of these systems and the masses of their components.

The new observatory will consist of two parts. One of these will comprise the 200-inch telescope, with its building, dome and auxiliary equipment, to be erected on the most favourable high-altitude site that can be found within effective working distance of the associated groups of investigators and their extensive scientific equipment. The other will be an astrophysical laboratory on the campus of the California Institute. This laboratory will serve as the headquarters in Pasadena of the observatory staff and the graduate school of astrophysics. Its equipment will include instruments and apparatus for the measurement of photographs, the reduction and discussion of observations and for such astrophysical investigations as can be made there to the best advantage. Its instruments for the interpretation of astrophysical phenomena will be designed to supplement those of the laboratories of the institute and the Pasadena laboratory of the Mount Wilson Observatory. It will also include an optical shop, but the astrophysical instrument shop will be housed in a separate building, to avoid the effects of the vibration of machine tools.

The value of a telescope depends as much upon the efficiency of the instruments and apparatus used to receive, record and interpret celestial images as upon its optical and mechanical perfection and its light-collecting power. In the present plan special emphasis is therefore laid upon the development of all forms of auxiliary apparatus, such as spectrographs and their optical parts; photo-

graphic plates of the various types required for astrophysical and spectroscopic research; radiometers, thermocouples and photoelectric cells; recording microphotometers and other forms of measuring machines; and laboratory apparatus for reproducing or interpreting celestial phenomena. The study of these auxiliaries will be pushed forward as rapidly as possible, in view of the fact that any results obtained will be immediately applicable in existing observatories and laboratories.

An observatory council, consisting of four members of the executive council of the California Institute, has been placed by the trustees in full charge of the design, construction and operation of the astrophysical observatory and laboratory. This council consists of Messrs. Robert A. Millikan, Arthur A. Noyes, Henry M. Robinson and George E. Hale (*chairman*). Through the courtesy of the Carnegie Institution of Washington, Dr. John A. Anderson, of the Mount Wilson Observatory, has been appointed by the observatory council as its executive officer, in direct charge of design and construction. An advisory committee, including Dr. Walter S. Adams, director of the Mount Wilson Observatory; Professor Frederick H. Seares, assistant director; Dr. Charles G. Abbot, secretary of the Smithsonian Institution; Professor A. A. Michelson, of the University of Chicago; Professor Henry Norris Russell, of Princeton University, and Professors Richard C. Tolman, Paul S. Epstein and Ira S. Bowen, of the California Institute, will aid the observatory council and Dr. Anderson in determining matters of policy. Many other leading astronomers, physicists, chemists, meteorologists and engineers in these and other institutions will be called upon for advice and assistance. Dr. St. John and Dr. King, of the Mount Wilson Observatory, who attended the meeting of the International Astronomical Union in Leyden, were requested to look up many matters calling for early decision, and the reports they have presented embody much valuable information kindly given by leading authorities on the design and construction of instruments.

The first decision of the observatory council and the advisory committee, supported by the unanimous opinion of every one consulted in this country and abroad, favoured the use of fused silica for the 200-inch and other mirrors of the large telescope.

President Gerard Swope and Dr. Elihu Thomson immediately promised the cordial co-operation of the General Electric Company, and work has been undertaken at West Lynn, Massachusetts, under the personal direction of Dr. Thomson. After coating with bubble-free silica the face of a 22-inch disk already in hand, a 60-inch disk will be undertaken, for use as one of the minor mirrors of the telescope. If this proves to be satisfactory, a still larger disk will be made before the casting of the 200-inch mirror disk is attempted.

A mathematical study of the optical design of the telescope, undertaken by Dr. Frank E. Ross, of the Yerkes Observatory, with the kind approval of Director Edwin B. Frost, has confirmed the selection of the ratio F:3.3 for the 200-inch mirror. The field of sharp definition in the principal focus of such a mirror will be small, but the possibility of photographing extremely faint stars, especially in the spiral nebulae, makes such a powerful concentration of light highly advantageous. Dr. Ross, who will devote himself to these optical problems during the coming year, also believes that a lens can be designed, for use in the converging beam, which will serve when desired to give a much larger field, also with a short equivalent focal length. It is planned to use a Cassegrainian combination with a ratio of F:10, having a sharp field 30′ (17 inches) in diameter, for spectrographic and other work. A coudé arrangement similar to that of the 100-inch Hooker telescope, permitting the images of celestial objects to be formed in a constant temperature laboratory, for study with large fixed spectrographs, radiometers or other auxiliary instruments, is also projected.

Dr. Pease has devoted considerable time to a study of the telescope mounting, which has been facilitated by his previous work in designing large instruments. Much additional study will be necessary, however, before even a preliminary design can be adopted, because of recent advances accomplished by telescope builders in this country and abroad. It is our hope that an equatorial design of the fork type, of sufficient rigidity to carry a 40-foot interferometer and meet other severe requirements, will soon be worked out. In this task we have been promised the co-operation of many leading engineers, including Mr. Gano Dunn, Mr. Ambrose Swasey and his associates of the Warner and Swasey Company, and others of wide experience.

The extensive investigation of auxiliary instruments that forms a prime feature of the general scheme has been begun and will soon be developed in various directions. Mr. George Eastman and Dr. C. E. K. Mees have generously agreed to deal with many of the special photographic problems at the research laboratory of the Eastman Kodak Company. A Zeiss recording microphotometer has been ordered and will be used in a comparative study of various forms of this instrument. Dr. Sinclair Smith will attempt to develop and improve the radiometer recently used very successfully by Dr. Abbot with the Hooker telescope in measuring the distribution of energy in the spectra of stars of several types, and work on other auxiliary instruments will soon be commenced.

A comparative study of several possible high-altitude sites has been undertaken. Precise measures of the seeing, rather than estimates, are desirable. Dr. Anderson accordingly devised a simple means of measuring the atmospheric oscillations of star images under a power of 600 with a 4- or 5-inch telescope, and Mr. Ellerman has tested it satisfactorily on Mount Wilson in comparison with the estimates of experienced observers with the 60-inch and 100-inch telescopes. Preliminary observations with this method by Messrs. Ellerman and Humason have been made at Palomar Mountain and "Horse Flats" (north of Mount Wilson), and some tests made by Dr. Abbot and Mr. Moore at Table Mountain show that this site, like the others, deserves careful examination. Dr. Hubble, with the kind co-operation of the authorities of the Grand Canyon National Park, is engaged in the investigation of conditions near the Grand Canyon and at other points on the high plateau area of Central and Northern Arizona. In this work he is having the cordial assistance of Dr. Slipher and the members of the staff of the Lowell Observatory. All this work will be facilitated by the loan of three sets of recording meteorological instruments by Dr. Charles G. Marvin, chief of the U.S. Weather Bureau, who has also kindly supplied us with many meteorological data for various sites in California and Arizona.

The policy of the observatory council, in all phases of this undertaking, is to bring into co-operation the most competent authorities in their respective fields. In the operation of the telescope the same policy will be maintained which has been followed

in the past at the California Institute and the Mount Wilson Observatory of inviting eminent authorities in astronomical and astrophysical research to use the instrument in connection with their investigations. It is hoped that in this way the astrophysical observatory will also become an international centre for research. The willingness of so many leading men of science to lend their assistance and the fact that all decisions have been unanimous give promise of such results as the broad-minded attitude of the International Education Board most certainly deserves.

GRAPHICAL METHOD FOR DETERMINING THE HOUR ANGLE OF A STAR FOR A GIVEN ALTITUDE

By F. Henroteau and M. S. Burland

The following graphical method for determining limiting hour angles, in which only a few straight lines are used, presents great advantages over the rather elaborate trigonometrical computations that would have to be made otherwise. As finding the limiting hour angle is an operation performed constantly by all observers to determine when a star is going to be easily observable, this modified method may perhaps be a convenience.

Figure 1 is a reproduction on a reduced scale of the actual graph used at Ottawa for this purpose. It represents two overlapping projections of the celestial sphere respectively on the planes of the meridian and of the equator. This graph is drawn for a latitude of 45°, which is nearly that of Ottawa. The scale on the outer part of the circle gives the declination; that on the inner part the altitude. The third scale is for the hour angle.

As an example, consider δ Cephei (22h. 25.4m., 57° 54′). Let us assume that the altitude at which we wish to start observing is 35°. In order to find the limiting hour angle, it is necessary to make the following simple construction:

In Figure 2 draw RT parallel to $H\ H$ at an altitude of 35°. Draw LM parallel to EE at a declination of 57° 54′, these will intersect at o. Join the extremity of LN to that end of EE, which is on the same side of the north line as the point o, and produce this to meet the vertical line through NP at A. Join Ao and produce it to cut EE at B. At B draw a line perpendicular to EE and produce it to cut the circle at D. This point D gives the limiting hour angle for observing that particular star at that altitude.

In the case of a star whose declination is near to zero a close approximation to the true value of the limiting hour angle may be obtained in the following way: As before draw RT and LM, where these intersect, draw a line perpendicular to EE and produce it to cut the circle. The reading at this point will give the desired value.

An explanation of this construction is easily arrived at by straight projective geometry. Indeed *RT* is the projection on the plane of the meridian of the small circle of given altitude measured by the arc *HR*. *LN* is the projection of the small circle of given declination (that of the star) measured by the arc *EL*. *o* is the

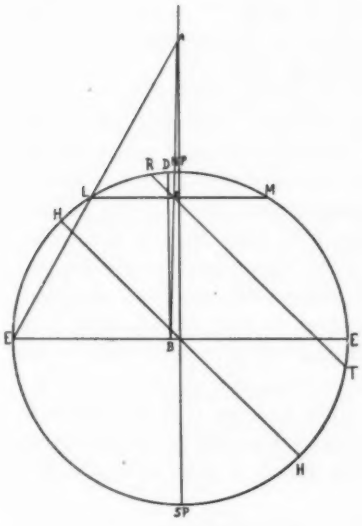

Fig. 1

Fig. 2

projection on the plane of the meridian of the intersection of these two small circles. To avoid constructing an auxiliary circle, the circle *LM* is enlarged to *EE* by conical projection so that the arc *ED* measures the limiting hour angle.

Dominion Observatory, Ottawa.
August, 1928.

Seminar No. 71, May 18, 1928.

EXPERIMENTS IN SPECTROSCOPY

The following outline is intended to point out some interesting problems in spectroscopy with applications to modern theory and to describe some experimental equipment used.

Hydrogen. The well known Bohr-Sommerfeld picture of the dynamic hydrogen atom with an electron revolving about the nucleus lends itself to easy interpretation in terms of spectral lines, and much work has been done on the spectrum of this element. Wood, Hulburt and others have obtained absorption of the Balmer series but a study of the fine structure of these lines in absorption should prove fruitful, since any faint components might become visible when some of the more intense radiations were absorbed. Two main obstacles present themselves in the experimental procedure, first, to obtain a source with the energy concentrated in the Balmer series and, second, to absorb any member of that series, $H\alpha$ being perhaps the most convenient. The way out of both difficulties has been shown by Prof. Wood by special design of the discharge tube and the use of three electrodes giving a high-tension and a low-tension discharge.

With suitable apparatus and some high-resolving power, such as that of a Lummer-Gehrcke plate, the fine structure of the radiations may be studied and any new distribution of intensities noted.

McLennan and Shrum and others have found two components to the lines of the Balmer series and conclusive evidence as to the presence or absence of further fine structure would furnish an important check on the selection principle, while the relative absorption of the components would furnish reliable information upon the metastability of the energy levels.

Ozone. Of late years the study of ozone has gained importance due to its connection with the aurora and upper atmosphere problems. A method, apparently reliable, for studying the effects of

temperature and pressure and the presence of various gases, upon the rate of production and decay of ozone is described.

The ozone is produced from pure oxygen pumped through a Siemens ozonizer. The ozonized oxygen is circulated by an all-glass circulating pump through a discharge tube one metre long and through the ozonizer, the temperature and pressure being variable, over a moderate range. The light from a quartz mercury arc is photographed by a quartz spectrograph after passing through the ozonized oxygen. Ozone has a strong absorption band in the ultra violet and the relative intensity of the mercury arc line at λ 2537 served as a criterion of the relative amounts of ozone present. Care was taken to see that no organic materials came into contact with the ozone.

Interesting results can be had with this apparatus which seems to promise well for the investigation of the catalytic and analytic effects of various gases upon the rate of production and decay of ozone.

Experiments along these lines were undertaken by the writer under the direction of Dr. G. M. Shrum at the University of British Columbia during the winter of 1927-1928. No definite results were obtained but indications were had that further effort along these lines would be worth while. In closing I should like to express my gratitude to Dr. Shrum for his continual assistance and interest during the experiments.

R. M. PETRIE.

REVIEW OF PUBLICATIONS

Amateur Telescope Making, edited by Albert G. Ingalls. 285 pages, 5½+7½ in. N.Y., Scientific American Publishing Co., 1928.

The present time might almost be described among amateur astronomers as the age of the amateur telescope. The small reflector, five, six, or even ten inches in diameter, can be constructed without elaborate machinery, at a very small cost, and will afford the maker an endless amount of pleasure. But guidance is necessary.

Several years ago the associate editor of the *Scientific American* became interested in the construction of a telescope and found it difficult to procure literature on the subject. The magazine appealed to such veterans as Porter and Ellison, and has been publishing from time to time advice to amateurs and details of the methods used, both in making the mirrors and the mountings. It has also published the experiences of many who have actually constructed telescopes for themselves. In this way great work in popularizing the subject has been accomplished.

These articles, with additions and arranged so as to form a treatise on the subject, are now in book form. The writer of this review has at one time and another constructed mirrors for a five, a twelve, and finally a nineteen inch and its mounting. If such a book had been available in the beginning of these labours many a failure would have been saved. Amateur telescope building is a fascinating hobby. To one who has an ordinary degree of mechanical skill and a delight in making something and making it well there is none better.

Any amateur astronomer who would like to have a telescope should buy this book; it will do the rest. It is interesting, enthusiastic and inspiring from the foreword by Dr. Harlow Shapley of the Harvard Observatory, through the articles by Porter, Ellison, Hastings, Thomson, to the final pages, about three hundred in all.

R. K. Y.

Astrometric and Photometric Statistics of Certain of Hagen's Fields Photographed with the 24-inch Reflector. By Harriet McWilliams Parsons. (Publications of the Yerkes Observatory, Vol. IV, Part VII.)

In this publication the writer investigates the positions, proper motions and magnitudes, photographic and photovisual, of comparison stars in eight of Hagen's variable star fields. These fields surround the variables S Cassiopeiae, U Arietis, V Tauri, R Camelopardalis, R Serpentis, R Draconis, R Vulpeculae and R Pegasi.

The 24-inch reflector at Yerkes was used to obtain the plates, which were then carefully measured on a screw measuring machine in order to obtain the star positions and hence their proper motions. In the photometric investigation the photographic and photovisual magnitudes were obtained from measurements with a Hartmann microphotometer of one hundred and thirty plates.

First, relative values of magnitudes were obtained, and to change these into a known system of magnitudes required the determination of a zero point. For the photographic magnitudes this was found by making free exposures of the same lengths on the same plate of the field investigated and a nearby Harvard standard field. For the photovisual magnitudes, zero points were determined by comparison with Kapteyn fields, using the photovisual magnitudes of stars determined by Professor Parkhurst.

This publication is extremely significant in that it furnishes positions and magnitudes of comparison stars with an accuracy which has rarely been attained. It is the only kind of photometry which will lead to important results, because it will permit the determination of the small fluctuations of light, so necessary when it comes to accepting or refuting modern theories of variable stars.

F. Henroteau.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

PROFESSOR RITCHEY'S ARTICLE

Four articles by Professor Ritchey on "The Modern Photographic Telescope and the New Astronomical Photography" have been printed in recent issues of this JOURNAL. The fifth will appear in the January number and two more (seven in all) will follow.

ANOTHER MONSTER TELESCOPE

In another place in this issue (page 428) is an account of the great project of constructing a telescope with a mirror 200 inches in diameter. Apparently Dr. G. E. Hale and his associates have convinced some persons who have the management of great wealth that such a telescope can be produced and be used to secure information which is worth the great expense involved.

The new instrument is to have double the linear dimensions of the 100-inch Hooker telescope but the difficulty in constructing it and the cost will likely be more nearly as the cube of the like dimensions, or eight times as great. The outstanding feature of the instrument will be the mirror which is to be of fused quartz. This is almost the ideal substance as it expands very little with a rise in temperature. But the discs of quartz so far produced are comparatively small, and one 200 inches in diameter will present enormous difficulties. It is to be hoped that those who are embarking upon this great project may live to see it completed successfully, but a forecast of the time is certainly hazardous.

BELLUM IN NEBULIS

Theories of cosmogony have a great fascination for many persons. Even an elementary work on astronomy is not considered complete without a discussion of the subject, but to propound and develop a new hypothesis demands a peculiar and powerful type of mind. There must be a comprehensive knowledge of the essential principles of several related branches of science and an ability to consolidate many apparently unrelated factors into a harmonious whole.

In the past we have had Kant, Laplace, Helmholtz, Kelvin and others, while the outstanding workers in this field at present are Jeans and Eddington. The good old nebular hypothesis of Laplace which appealed so strongly to everyone has been shown incapable of explaining the formation of the solar system, but the idea of loss of heat and contraction of a great gaseous mass is so simple and so reasonable that one finds it easy to believe that many of the suns of space are developing in that way.

About 1901 Professors Chamberlin and Moulton, of the University of Chicago, outlined a new theory which they called the Planetesimal Hypothesis. It was very different from Laplace's theory. The latter postulated in the beginning the simplest kind of body, a ball of gas, and traced its development into our complex solar system; the new theory began with two full-grown suns which gave birth to something hardly more complex—just as a new-born child is quite as complex in structure as its parents. It was pointed out that there were thousands of spiral nebulae in the sky and from one such it was contended that our system developed. It was pointed out that a spiral nebula might be formed by the interaction of two suns which in the course of their motions through space happened to come near each other. Indeed the new theory was sometimes called the spiral nebula hypothesis. This part of the theory, I believe, is now discarded.

During the last fifteen years attempts have been made to introduce recent atomic developments into cosmic theories, and some of these have been attached to the Planetesimal Hypothesis, or something like it. In an article in "Science" for December 7, 1928, Professor F. R. Moulton who, as an astronomer, collaborated with Chamberlin, who was a great geologist, in the development of the new theory, criticises severely Eddington, Jeans and Jeffreys for neglecting to give proper credit to the originators of the Planetesimal Hypothesis. He also attempts to show how inconsistent, untenable and "astounding" some of the conclusions reached by these English scientists are.

It is certainly very interesting to see this "war in the heavens", and the outcome can only be a clarifying of the intellectual atmosphere—if indeed it is possible to clear up an essentially nebulous condition.

C. A. C.

MEETINGS OF THE SOCIETY

AT WINNIPEG

The regular monthly meeting was held in Theatre A, University Science Building, April 11th, at 8.15 p.m. The President, Mrs. E. L. Taylor, was in the chair.

The lecturer of the evening was Professor V. W. Jackson of Manitoba Agricultural College, his subject being "Home-made Star-Clocks and Sun-Dials."

In his opening remarks Professor Jackson referred to the fact that, owing to the standardized system of time now in use, time in Winnipeg was 28 minutes ahead of apparent solar time as shown by a sundial. This arose because though Winnipeg was on the 97th meridian its time was governed by that at Fort William, on the 90th meridian. Home-made star-clocks were displayed by Professor Jackson, who explained the simplicity and economy of their construction, emphasizing their accuracy, if properly constructed. At the present time he stated there was a world-wide wave of interest in the study of astronomy. In many countries people are becoming intensely interested in the wonders of the universe. In Los Angeles there is a branch of an astronomical society of which only those who have constructed their own telescopes are permitted to become members, and in connection with this Professor Jackson suggested the formation of a "Telescope Makers' Club" under the capable leadership of Mr. David Saunders, Treasurer of the Winnipeg Centre.

A course in elementary astronomy is being prepared for the schools, and he added that the star clocks which he was displaying would serve as models from which students would construct copies.

A short talk on Springtime Constellations, illustrated by slides, was given by Mr. A. W. Megget.

At a special meeting held on Friday, May 25th, the Winnipeg Centre had the pleasure of listening to an illustrated lecture given by Dr. R. Meldrum Stewart, Director of the Dominion Observatory at Ottawa, who spoke on "The Observatory and its Work." The President, Mrs. E. L. Taylor, was in the chair.

Mr. Stewart made an interesting personal reference to Manitoba being the place of his birth, saying he was born at a little hamlet now known as the town of Gladstone, where his father was a home missionary in the late 70's.

The lecturer first briefly outlined the history of the study of astronomy in Canada, showing that it was first taken up seriously during railway construction in the early '80's, when certain calculations could be made accurately only by the aid of astronomical observations.

One of the important functions of the Observatory is to broadcast daily the correct time, and the lecturer gave a very full description of this operation. By means of the transit instrument the observer notes the exact moment that any given star crosses the meridian, and simultaneously presses an electric key causing a mark to be made on the strip of paper on which the beats of the astronomical clock are electrically recorded. These clocks placed on individual concrete piers in the basement of the building, so they will not be affected by vibrations of any kind, are enclosed in glass cases from which the air is partially exhausted, and are kept at a constant temperature. They are marvels of precision, showing last year a variation of only 1/200 of a second.

Slides were shown indicating the relation between sun-spots and the weather and crop production. This is a subject engaging the attention of the Observatory at present which, it is expected, will eventually furnish a basis for much more extended weather forecasting.

Three different models of seismographs were illustrated. This instrument registers even the slightest earth tremor, and several very interesting records of earthquakes were shown on the screen. From data supplied by the seismograph, reliable advice can be given as to the best location for large buildings and heavy structures.

At the conclusion of the lecture a very cordial vote of thanks was tendered Mr. Stewart; and the Executive of the Society held a reception in honour of Mr. Stewart at the home of Mrs. E. L. Taylor, President of the Centre.

S. C. Norris,
Secretary.

AT TORONTO

October 9, 1928.—The regular meeting was held in the Physics Building of the University. Professor Chant occupied the chair.

Mr. Hunter spoke briefly on his observations during the past summer, particularly about the appearance of the aurora. Mr. Collins also made some remarks on his observations, and Prof. Chant spoke of having viewed the aurora from on board ship in mid-Atlantic.

Dr. R. K. Young was then called on by the Chairman for the address of the evening. The subject was "Some Problems in Astronomy". The speaker stated that before we can study any subject we must proceed to name and classify the objects with which we have to deal. We find that the earliest observations in astronomy have to do with the naming of the stars and the formation of catalogues. The earliest catalogue preserved is that due to Ptolemy, which contains about 1000 stars. This work has been extended by Tycho Brahe, Bayer, Flamsteed, Argelander and others, so that at the present time we have identifications for millions of stars. Having shown how the stars were identified the lecturer took up in turn the items of interest which we desire to know about them,—their motions, their distances, their constitution, whether variable, double, or single. Information on all these subjects is contained in various catalogues, some of which were shown. These volumes, which represent the life work of a host of distinguished observers, stand as a monument of past industry, and remind us

that we owe a debt to future generations to continue this work and hand down to posterity a fitting continuation of the immense work already accomplished.

October 23.—The regular meeting was held in the Physics Building of the University of Toronto, Mr. J. R. Collins in the chair.

The following were elected to membership in the Society:

B. M. Kinser, Eustis, Florida, U.S.A.
Miss L. M. Harris, Port Perry, Ont.
Miss E. A. Power, 98 Weber St. East, Kitchener, Ont.
Miss A. H. Kelly, 610 Simcoe St. West, Oshawa.
Roy A. Peterson, Edson, Alberta.
Arthur B. McKim, 9227 83 Avenue, Edmonton, Alta.
Rev. Oswald W. Whitford, B.A., Berwyn, Alta.

Mr. A. F. Hunter noted the positions of Venus and Mars and other interesting objects were quoted from the HANDBOOK.

The Chairman spoke of the presence of Mrs. E. L. Taylor, President of Winnipeg Centre, and asked Mrs. Taylor to address the meeting. She then expressed her pleasure at being at a meeting of the parent Society, and spoke of the enthusiasm of some of their members in Winnipeg, and of their plan to have frequent observation meetings, also the good attendance at their meetings.

The Chairman then introduced to the audience a booklet containing star maps by Prof. H. R. Kingston, of London.

Mr. A. R. Hassard was then called on for his notes and observations. He spoke in happy terms of the new book, "Our Wonderful Universe", an easy introduction to the study of the heavens, by Prof. C. A. Chant. Mr. Hassard remarked on the height of the water in the Great Lakes, it being at a much higher level than during the last few years. He had viewed the meteors during August, part of the time seeing a meteor every three minutes, chiefly in the eastern sky, these comprising what had been Biela's comet before it was shattered into meteors. He thought that the interest shown at the Canadian National Exhibition, by the public, in observing at the telescopes should be considered by the Society. Mr. Hassard pointed out that Mars was becoming brilliant, high in the sky and would be interesting for the remainder of the autumn.

Mr. A. F. Hunter was then called on. He had observed on July 7-8 a severe magnetic storm, and beginning on August 1 a four-days' period of heavy thunderstorms, August 26-7 an auroral display, notably pulsating, and September 19 marked evidence of similar disturbances.

Mr. Hunter also showed an old book, printed in 1855, "An Astronomical Philosophy", by a Mr. Hutchinson, being the oldest Canadian book on Astronomy known to the speaker. Also a copy of the "Palimpsest", containing an article on the Amana meteor of Feb. 12, 1875. Amana, Iowa being the place where it fell.

November 6.—The regular meeting was held in the Physics Building of the University at 8 p.m. Mr. J. R. Collins in the chair.

The lecturer of the evening was Dr. C. A. Chant, who gave an account of the meeting of the International Astronomical Union at Leyden, Holland, July 5-13, and the Astronomische Gesellschaft in Heidelberg, July 18-21.

The attendance at the former consisted of about 250 astronomers, representing 28 nations. The meetings of the committees and of the General Assembly were described, and an account of the various receptions and other forms of entertainment given.

The meeting at Heidelberg was international in nature, and the reception to the foreign astronomers by the Germans was very cordial. A fuller report is to be found in the JOURNAL for November.

The lecture was illustrated by splendid pictures taken by Dr. Chant, and was much enjoyed by the large number present.

November 20.—The regular meeting was held in the Physics Building of the University of Toronto at 8 p.m. Mr. J. R. Collins in the chair.

The following were elected members of the Society:

Mrs. F. J. Millership, 387 Sherbourne St., Toronto.
Mr. Robert E. Buckley, 1 Sutherland Ave., Danforth, Toronto.
Mr. Emerson W. Bullock, Brampton, Ontario.
Rev. Harold Nelson Cutler, 91 Ilford Ave., Arlington, N.J.
Mr. R. C. Chamberlain, 221 Silver Birch Ave., Toronto.

The lecturer of the evening was Dr. Ralph E. DeLury of Ottawa on the subject "What We Know About the Sun".

Dr. DeLury covered the subject in a very interesting and exhaustive manner. He referred to his observations of sunspots, their rotation, pulsations in sunspot numbers, the period or cycle being about eleven and a half years. He dwelt at considerable length on the accompanying variations on the earth, on relations to terrestrial magnetism, temperature readings, the appearance of the Aurora Borealis, rainfall, tree growth, migration of birds. Commodity prices seemed to follow the cycle, as also the growth of grain, and the scarcity or abundance of animal life as instanced by the case of rabbits in Canada.

Variations in the solar corona coincident with sunspots were noted. The lecturer stated that the ejection of matter from the sun into interplanetary space was a possible cause of variation in the Solar System. Ultra violet light changes profoundly with the sunspot variation, and, according to Dr. DeLury's view, is probably the cause of many of the foregoing changes.

The sun's place in the universe, and in the progression of the temperatures and types of stars, was discussed; also its position in a spiral nebula. Other spiral nebulae, their distances and motions, were explained with some fulness.

The thanks of the meeting were tendered to Dr. DeLury by the Chairman for his most instructive and informing address.

E. J. A. KENNEDY,
Secretary.

AT LONDON

The regular October meeting was held in the Conference Room of the London Life Building on Friday, Oct. 12, at 8.15 p.m.

The Secretary reported that the executive had met and outlined a programme of meetings for the next four or five months. Dr. H. R. Kingston gave a short talk on the planet Venus and urged the members to follow the changes in position and brightness of Venus for the next few months. Mr. T. C. Benson gave an interesting account of a bright band of light observed by him on September 7 last, from a point some 60 miles north of Belleville, where he was spending his

holidays. He reported that the band varied in width from two to four degrees and extended from the east horizon to the west. The light was fairly steady and the phenomena lasted for an hour. Mrs. Hungerford reported observing a similar band at Lake Louise in September. The band starting from the constellation of the Great Bear. The Secretary and Miss A. Callard reported observing an unusually brilliant display of Northern Lights on August 25.

The major address of the evening was given by Dr. Ainslie on the Northern Lights. The lecturer pointed out that the Northern Lights in early days were thought to presage war. The phenomenon is seen most frequently in higher latitudes, occurring very frequently in Shetland Islands, Orkney Islands and in Labrador. In northern parts of England it is seen as often as 200 times a year, but at Gibraltar about once a year. Dalton was the first to attempt to measure the height of the aurora; he placed it at 60 miles above the earth. A number of theories have been put forward to explain the phenomenon, and in recent years experimental work has been carried on in Toronto by Dr. J. C. McLennan in an effort to establish one of the theories. One theory is that the Northern Lights are caused by electrical discharges in the presence of gases which have been subjected to extreme cold such as would be found in the atmosphere at high altitudes. Dr. McLennan used nitrogen gas in 1920 and produced effects much like the aurora. He next used oxygen and helium mixed and produced effects more like the aurora. Again he used neon gas and helium and produced effects practically identical with the aurora. Dr. Ainslie pointed out that auroral displays are at a maximum when there is a maximum of sunspots, which suggests that the sun has something to do with this phenomenon. Much interest was manifested in the lecture and a spirited discussion followed.

The regular November meeting was held in the London Life Building on Friday, November 9, at 8.15 p.m. The President, Dr H. R. Kingston, named Mr. McKone and Mr. Coates to audit the Treasurer's books for the year 1928. Arrangements were made for a social hour in connection with the Annual Meeting to be held in the Normal School December 14, refreshments to be served.

Mrs. F. Anderson and Mr. and Mrs. Wendell Holmes were elected members of the Society.

Miss N. Morris then gave an interesting address on the planet Jupiter. The planet was compared with the earth in size and weight. Jupiter's diameter is 10 times that of the earth and its mass is 317 times that of the earth. The planet rotates on its axis once every 10 hours, but all parts do not rotate at the same rate. The planet is surrounded by a cloud envelope and the bands seem to be due to the cloud envelope. Attention was directed to the great Red Spot which is subject to so many changes. Jupiter has 9 satellites, 4 of which were discovered by Galileo in 1610. The speed of light was discovered by a Danish astronomer through a study of the motions of Jupiter's satellites.

Mr. T. C. Benson then exhibited an excellent heliocentric chart which he had constructed, and with it demonstrated the relative position of the planet Venus. Dr. Kingston made some further explanations and showed how the chart can be used from time to time to show the motions of the planets and how to determine the change in their relative position from month to month.

E T WHITE,
Secretary-Treasurer.

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